Using Flow Charts to Visualize the Decision Process in Space Weather Forecasting

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Abstract

Our society today relies heavily on technological systems such as satellites, navigation systems, power grids, and aviation. These systems are very sensitive to space weather disturbances. When Earth-directed space weather driven by the Sun arrives at the Earth, it causes changes to the Earth's radiation environment and the magnetosphere. Solar Energetic Particles from the sun can endanger life in outer space, and geomagnetic storms can severely impact critical infrastructure near and on Earth, such as the power grids and satellites. **These adverse effects can be lessened through the early warnings sent by space weather forecasters.** A space weather forecaster's duty is to send advanced notifications to tech industries and NASA missions so that they can take extra measures for protection. Decisions are made by following certain steps and processes from the time an event occurs at the Sun, all the way to the impact locations. **These decision making processes are complex, thus a flow chart is created to help forecasters visualize the decision making processes. This flowchart provides basic knowledge of space weather and can be used to train future space weather forecasters.** The flowchart is also a great reference for people who are already familiar with space weather.

Forecasting Methodology

Space weather forecasters measure and analyze space weather events using various tools and models developed at the Community Coordinated Modeling Center (CCMC - http://ccmc.gsfc.nasa.gov/) such as:

- iSWA (iNtegrated Space Weather Analysis System) - allows forecasters to observe various graphs and models (called cygnets). (http://iswa.gsfc.nasa.gov/)
- SWPC_CAT and StereoCAT (CME Analysis Tools) - measures parameters of Coronal Mass Ejections (CMEs) to be entered into simulations.
- WSA-ENLIL+Cone - Models CMEs and predicts impacts at various locations.

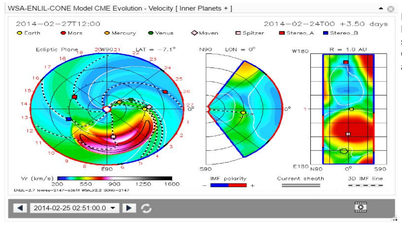


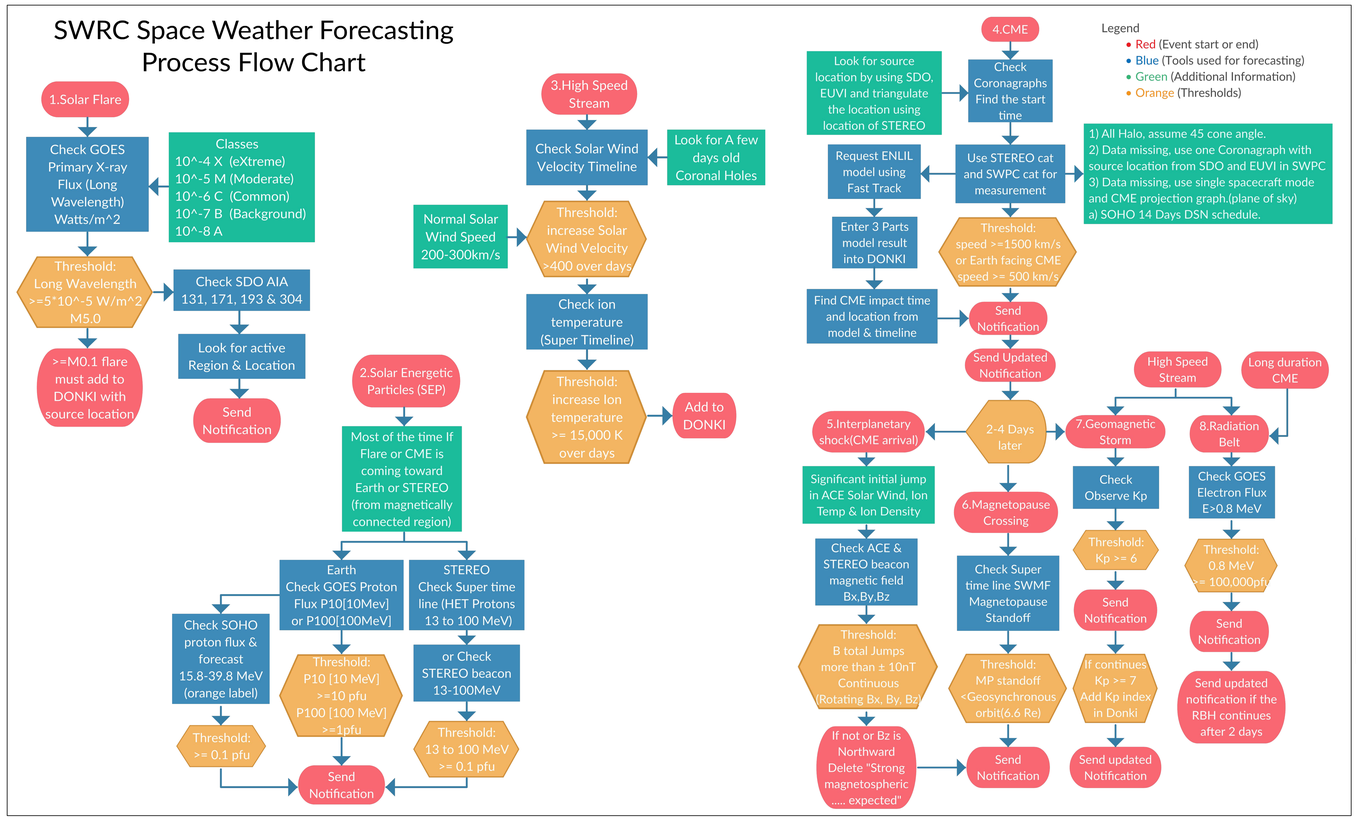
Figure 1: WSA-ENLIL+Cone Model showing the velocity of the CME and the predicted arrivals.

- Warnings and notifications are then sent through Space Weather Database of Notification, Knowledge, Information (DONKI - https://kauai.ccmc.gsfc.nasa.gov/DONKI/)

Space Weather Impacts

- Solar Flares can produce strong X-rays that block high-frequency radio waves (Radio Blackout Storm).
- Strong Solar Flares and CMEs can produce Solar Energetic Particles (SEPs) that can endanger life in outer space and can penetrate satellite electronics, causing electrical failures.
- High Speed Streams and CMEs can produce magnetic reconnection that can cause Geomagnetic Storms and Radiation Belt Enhancements.
- Geomagnetic Storms cause Satellite Drag that can affect spacecrafts at low Earth Orbits, Data scintillations, Power Grid failures and Aurora.
- Radiation Belt Enhancements can cause internal charging that may damage satellites.

SWRC Space Weather Forecasting Process Flow Chart



Conclusion

Space Weather is increasingly important for today's society. We rely heavily on high-tech systems that are easily disturbed and damaged by space weather. It is important to train next generation of space weather forecasters, who will develop forecasting procedures and sophisticated models that will ultimately enable them to predict solar storms accurately. This flowchart can play a role in training them. Also as we approach the space exploration era, space weather forecasting is necessity for the safety of astronauts.

Acknowledgements

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References

Figures 1 - 4: iSWA (http://iswa.gsfc.nasa.gov/iswa/iSWA.html)

Figure 5: (https://kauai.ccmc.gsfc.nasa.gov/DONKI/)

SWRC (http://swrc.gsfc.nasa.gov/main/)

SWPC (http://www.swpc.noaa.gov/impacts)

CCMC (http://ccmc.gsfc.nasa.gov/)

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Flowchart download link: (https://goo.gl/94pTYn)

X4.9 Solar Flare Event

1.Solar Flare

- Solar flares are intense brightening events on the surface of the Sun with different intensities and durations.

Check GOES Primary X-ray Flux (Long Wavelength) Watts/m^2

- Flares are classified by X-ray flux and detected using the GOES Primary X-ray Flux Timeline in iSWA.

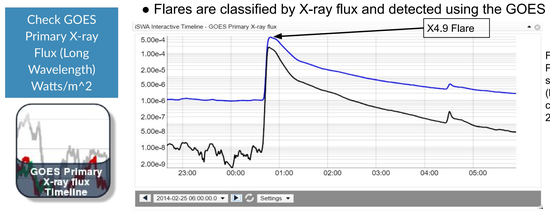

Figure 2: GOES Primary X-ray Flux showing 0.1-0.8 nm (blue) X-rays with X4.9 class flare peaks at 2014-02-25T00:49Z.

Classes
10^-4 X (eXtreme)
10^-5 M (Moderate)
10^-6 C (Common)
10^-7 B (Background)
10^-8 A

- Flares are classified by X-ray flux, with X being the highest and corresponding to a flux of greater than 10^{-4} W/m2.

Threshold: Long Wavelength >=5*10^-5 W/m^2 M5.0

- Increased X-ray flux is an indication of a possible solar flare that may also be generating energetic particles leading to a solar energetic particle event (SEP). As a general rule of thumb space weather forecaster use M5.0 as threshold for sending a warning notification.

Check SDO AIA 131, 171, 193 & 304

- SDO/AIA images from iSWA are used to look for flares.

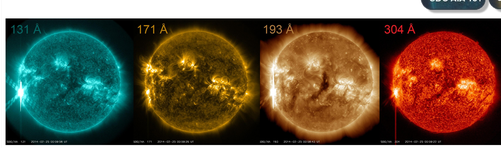

Figure 3: Series of SDO AIA images showing the 2014-02-25T00:59Z X-class flare in four different wavelengths. The different colored images show different wavelengths of light in angstroms. Different wavelengths show different temperatures and therefore different regions of the Sun. The temperatures vary from 4000 Kelvin to 10 million Kelvin.

Look for active Region & Location

- Magnetic connectivity solarscape viewer is used to identify the exact location of flares and active regions.

Active Region: #11990
Lat: -15 Lon: -76.5 Radius: 1.8
Mag Class: Alpha
NOAA Generated: 2014-02-25
Distance to Earth: 118.04
Distance to Mars: 154.52
Distance to Mercury: 118.04
Distance to Venus: 119.18

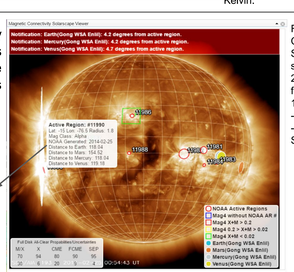

Figure 4: Magnetic Connectivity Solarscape Viewer showing the 2014-02-25T00:59Z X-class flare at active region 11990 with Latitude -15 and Longitude -76.5 on background SDO 193.

>=M0.1 flare must add to DONKI with source location

- Adding event into Space Weather Database of Notification, Knowledge, Information. (DONKI)

Send Notification

- DONKI is used to send space weather notifications.